# Combining New and Existing Technology to Enhance Future Naval Meteorological and Oceanographic (METOC) Data Systems

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*ABSTRACT*

*This paper presents a brief description of the Meteorological and Oceanographic (METOC) system and a discussion of various aspects of the METOC database that emphasizes the importance of combining new and existing technology. The METOC database components were designed according to a database-centric architecture to assists the users in obtaining up-to-date information from the DII/COE compliant METOC system. The Meteorological and Oceanographic (METOC) database is a dynamic, distributed database that conforms to the DII/COE requirement of providing general availability to all users of the system. Several key aspects of METOC database technology are of interest to various users who have special requirements. Because each key aspect must be implemented in concert with users requirements, some adaptations may be necessary. The most important feature of a database server from the user perspective is its capability to deliver to the user the required information in a timely and user-friendly manner. This paper discusses various aspects of the impact of technology evolution on METOC database and its impact on the system design and development cycle.*

## I. INTRODUCTION

The Meteorological and Oceanographic (METOC) database is dynamic, distributed database that conforms to the Defense Information Infrastructure Common Operating Environment (DII/COE) specification of providing general availability to all users of the system. It is dynamic because it is filled with perishable, environmental data that are ingested, updated, and deleted on a regular and real-time basis. The METOC database is distributed not only with respect to the

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physical locations of its distributed data repositories, but also with respect to the applications that access the METOC data. It consists of six shared-database segments that comply with the requirements DII/COE level five [8].

As is the case with any database, each of several key aspects of METOC database technology is of interest to various specialists in the technical community. For example, data administrators want to be sure that the design of the database structure meets the needs of the organization as a whole. Database developers and engineers implement the mechanics of designing, building, and integrating databases and meta-databases to achieve specific goals within the larger context of the software and system(s) that the data support. (See, for example, [4].) Database administrators are concerned with updating the database, providing users with accounts, maintaining user profiles, and with the overall reliability and maintainability of the database system.

Finally, one must consider the METOC users' perspective. The most important feature of a database to the user is its capability to provide that user (or the user's software) with access to timely, accurate, up-to-date, consistent and user-friendly data. This paper presents a discussion of various aspects of the METOC database that emphasizes the importance of technology and its effect on the user.

## II. DESCRIPTION OF EXISTING METOC DATA SERVER AND DATA-ACCESS METHODS

### Data-Centric View

To eliminate the "stovepipe" and segregated databases, the METOC database takes a unified database topology where quality-controlled data can be disseminated to the applications and users in a coherent manner. The METOC database system is a data-centric server as opposed to an application-based or process-oriented system. This data-centric architecture is similar to some existing environmental systems [10] as well as $C^3I$ [1] systems that use the METOC data. From the $C^3I$ systems experience, this data-centric architecture has been shown to be of great utility in assisting users with their data-access tasks.

Currently, the preferred method of data access in the METOC system is via application-program interfaces (APIs) [8, 9]. These APIs provide the users and their applications with storage, retrieval, maintenance and distribution of METOC data and products [8]. APIs fall into three categories: American National Standards Institute (ANSI) Structured-Query Language (SQL) APIs; Tactical Environmental Data System (TEDS) APIs [8]; and Operating- and File-system service APIs [8]. ANSI SQL-92 is incorporated into the API code to make these APIs independent of any specific database management system (DBMS) vendor enhancements to SQL. Access via direct, ad hoc SQL query is a secondary method of data access that is recommended only for the database system administrators or when APIs are inappropriate.

## METOC Data-Server Design

A data-perspective modeling of the METOC data reveals that five basic METOC data types can be abstracted. Since the original analysis [9] of the METOC data, two additional data types have been created and augmented for the database. In addition to the observations, numerical-prediction model output, and image types, the TEXT data type, and CLIMATOLOGY data type have been added. The additional data types are demanded by the users to handle those data related to the dynamic data of the METOC environment. Most of the textual data are in the area of plain-text warning messages. Although they do not record continuous variables of the nature environment (e.g. temperature of the atmosphere or ocean), they do record a particular event or phenomenon of the nature environment such as a tornado or a tsunami. The climatology database contains the "average" conditions of the natural environment. It often serves as a background and describes the range of expectation. With the additions of these two data types, any plain text or fixed METOC data sets can be adapted to these two types.

The most challenging aspect of the design of a data-centric METOC database is to provide a foundation for equal efficiency of handling of all five data types (or all six DII/COE database segments). Each segmented data type has its own particularities in terms of characteristics of the data volume and traffic. Observations are short (hundreds of bytes) with large volume (about two million records a day). Numerical model outputs have finite data sets, but they arrive at database in bursts (twice a day, about 200-500 Mbytes each time). The image data reach the database regularly at 50 Mbytes every hour. Text observations are very infrequent and short (hundreds of bytes). Fixed data sets, in general, are the easiest to handle, since the usage of these data sets is defined.

When an application or a user extracts data from the database server, a performance degradation may be experienced if the same schema for the observations is used to serve the numerical model output. METOC data server design in the current implementation can take advantages of the "segmented" architecture provided by the DII/COE. Each data type is a segment and can be implemented separately on separate servers. The advantage is two fold:

- not all data types have to be implemented on one server, and
- network segmentation can be done naturally.

For example, if the satellite segment is implemented on the satellite data server, the network will not experience the bulk of the image transfer traffic. In summary, the five METOC data types are implemented over six independent database segments. Since the original implementation [8], the observation data type has been further divided into two segments to enhance performance. The volume of the satellite observations is about 104 times greater than that of the conventional observations.

# III. COMBINATIONS OF EXISTING AND NEW TECHNOLOGY IN THE METOC DATA FLOW

METOC data are supplied to a variety of Naval systems, including but not limited to the Joint Operational Tactical System (JOTS) and Joint Maritime Command Information System (JMCIS) [2, 3]. This is accomplished through a process of data flow. METOC data flow is an important feature in JMCIS. The METOC data flow is described below as an example of how existing (E) components will interact with new (N) ones. "(E,N)" denotes existing components with planned upgrades. The following is a plan for METOC data to flow into and out of specific components of the Tactical Environmental Support System/Next Century (TESS NC) [8] and JMCIS.

The existing Officer in Tactical Command Information Subsystems (OTCIXSs) (E) provide the following data to the JOTS 1 ingest (E) platform: Over-the-horizon-Targeting Gold (OTH-T-Gold), GRID, Bathythermogram (BT), Radiosond (RDSND), MUNIT, NUNIT, and OVLY2. At this point, the data stream divides and two streams result. From the JOTS 1 ingest (E), one data stream containing the OVLY1 data flows into the JOTS 1 Global database (E) and the remainder of the data stream, which contains OTH-T-Gold messages, flows to the METOC OTH-T-Gold decoder-encoder (E), where another branch in the stream occurs. One branch, consisting of RDSND, MUNIT, and NUNIT data, populates the JOTS 1 Global database (E). The other branch, consisting of Gridded Binary (GRIB) and Binary Universal Form Representation (BUFR) data, is described below.

### Data Filter and Alert Software

This particular arrangement of data flow, of which GRIB and BUFR are examples, will occur in several places throughout the data-flow configuration. Therefore, it is describe here for future reference. GRIB and BUFR data are fed into a filter (N), METOC database (N) and alert software (N) arrangement in the following manner. Data enter the filter-application software (N), in which the user can define thresholds for various conditions of the data. When the data have passed through the filter, they are stored in the METOC database (N) for further display, analysis, and/or processing. When an event is detected that is of special interest to a user, a threshold is exceeded and a flag is raised in the filter software, which produces an "alert" message (N) on the user's screen. This screen could reside on the same hardware platform as the filter-application software (N), or it could be on a different platform. This completes the description of the OTCIXS data flow, which includes a mixture of existing and new capabilities. (For the purpose of this paper, this "filter-alert-database arrangement" is called the Alert-Threshold System (ATS).)

### Naval Modular Automated Communications System

The next data flow of interest pertains to the Naval Modular Automated Communications System (NAVMACS), which provides Optimal Ship-Track Route

(OSTR) information and warnings, etc. These data are fed into the JOTS 1 ingest (E) machine, and thence to the JMCIS Central Database System (CDBS) (E), and thence to message applications (E).

METOC Image Format (MIF) data, originally from a AN/SMQ-11 via the Secret Internet Protocol Routing Network (SIPRNET) or the Naval Internet Protocol Routing Network (NIPRNET) (E), enter a filter application (N) described above in the section, "Data Filter and Alert Software." (See also data-flow description pertaining to the MINI Rawinsonde System (MRS).) Here, metadata pertaining to MIF are screened and alerts are issued to the user's screen on the basis of some previously defined metadata features. MIF data flow into an application (N) that will store MIF, and thence to an NT File Server (E). From this file server, MIF data flow to a viewing and conversion application (N) that will allow users to see MIF images on the NT File Server (N). This application will allow the user to select specific MIF files and store them in NITF format on the Image Translation Server (ITS) (E). From ITS (E), image metadata are transferred to the JMCIS CDBS (E). Everything in this figure depicts new capabilities, except the NT file server, the ITS, and the JMCIS CDBS.

Shipboard Meteorological and Oceanographic Observing System (SMOOS) data have two separate but related data-flow paths. SMOOS sensor data flow into a SMOOS ingest (E,N) module. From there, BUFR data are transferred into another ATS (N) described above.

Another data path begins with global and/or local observations (Obs), including upper-air Obs, Terminal Aerodrome Forecasts (TAFs), BTs, and warnings. These data sets are transmitted to a module called "Other Serial Ingest," (E,N) from whence World Meteorological Organization (WMO) and BUFR data proceed to another ATS (N). MRS data flow into the METOC/MRS/OTH-T-Gold decoder-encoder (N), and thence to the JOTS 1 JMCIS Global database (E). The MRS data also flow through the filter-alert-database arrangement (N), now called the ATS.

**Data Sets From SIPRNET and NIPRNET**

This section explains the origin of various data sets from SIPRNET, including, but not limited to MIF data. SIPRNET or NIPRNET (E) provides a group of data sets called "METOC BUNDLE" to a "METOC Pull/Retrieve" (N) module. METOC BUNDLE can contain multiple data sets with several items of interest, including MIF, BUFR, GRIB, WMO, and OTH-T-Gold. The "METOC Pull/Retrieve" (N) module has a graphical user interface (GUI) for the user to specify the data sets to get from Fleet Numerical Meteorological and Oceanographic Center (FNMOC) and regional center, or any METOC database. Data in a compressed format proceed from the "METOC Pull/Retrieve" (N) module to an "UNPACKER" (N), module that "unpacks" the data. MIF data sets are among the unpacked data that serve as input into the following data flow: MIF data are filtered through an ATS and sent to an NT platform. There, these data are converted manually from MIF to National

Image Transmission Format (NTIF) and are sent to an ITS. Similarly, the other data sets, BUFR, GRIB, and WMO, also proceed through the data pathways consisting of other ATSs (N). The exception is OTH-T-Gold, because these data undergo an extra step between the UNPACKER (N) and the ATS (N). From the UNPACKER (N), OTH-T-Gold data flow through a METOC OTH-T-Gold Decoder (N), the output of which consists of the GRIB and BUFR data. These GRIB and BUFR data flow through the ATS (N). Conceptually, one can have a separate ATS for each data type to which this pertains. However, the actual implementation may result in a single set of filter-alert-database software that is capable of detecting and processing multiple data types from a variety of different sources.

SIPRNET or NIPRNET (E) provides a variety of files to the office-automation briefing tools (N). The user can transfer files via three main data pathways. First, the user can transfer images and documents between SIPRNET or NIPRNET (E) directly to the office-automation briefing tools (N). Second, the user can transfer files via File-Transfer Protocol (FTP) between SIPRNET or NIPRNET (E) and the NT File Server (E). Third, the user can store and access office-automation files and briefs from the NT File Server (E) into the office-automation briefing tools (N).

**Data Inputs and Outputs and Forecast Tools**

This section describes inputs and outputs of the NT File Server (E), the METOC Database (N) and the JOTS 1 Global database (E). The NT File Server (E) will supply products to the forecaster tools (N). Forecaster tools (N) also can store new products on the NT File Server (E).

The forecaster tools (N) also will interface with the "METOC database interface" module (N), which will be capable of interacting with many other components. For example, the "METOC database interface" module (N) will be capable of interacting with the METOC database (N), the JOTS 1 Global database (E), and the JMCIS CDBS database (E). One of the new technologies being combined with existing systems is more extensive use of access to METOC data via the World Wide Web [7]. More specifically, the "METOC database interface" module (N) will store and retrieve data from the METOC database (N) via three modes of operation: APIs, Ad Hoc Queries (AHQ), and Web. The Web mode of METOC database access is as follows: Data flow to and from a METOC Web SERVER module (N), which interfaces with a database-to-web converter (N). The database-to-web converter (N) is connected to the METOC database (N) to provide a method for multiple users, both meteorologists and fleet users, (such as TAMPS, etc.) to view, and in some cases, update METOC data.

"METOC database interface" module (N) will interface to the JMCIS JOTS 1 Global CDBS, TDBM, etc. database (E) via "Non-METOC Customers" software (N). Finally, the "METOC database interface" module (N) will be capable of interacting with the JMCIS JOTS 1 Global CDBS, TDBM, etc. database (E) via the COP (E) - NITES

II applications (N). Data will flow into and out of the database via the COP (E) - NITES II applications (N).

## IV. POTENTIAL IMPACT OF NEW TECHNOLOGY ON THE METOC DATA SERVER

The computer industry has produced much-matured software and hardware products since the implementation of the METOC data server in 1997 [8]. All of these commercial software and hardware products have gone through years of development cycles. A few of these technologies have matured enough that METOC community must pay attention to them and perform analyses to examine if these technology can be harvested to improve the METOC database system.

### Advances in Metadata

METOC database is a metadata system. The metadata schema is implemented on a relational database management system (RDBMS) while the bulk of the data themselves are left as either flat files or a binary large object in the RDBMS. Among all metadata advances (e.g. data warehouse), a key development for the spatial data in the federal government is worthy of attention. Using the data warehousing concept, the metadata sever can be used to dispatch the request to a physical data node and also can be used to house the middleware for data-access methods and translations. The Federal Geographic Data Committee (FGDC) has defined the Content Standards for Digital Geospatial Metadata (CSDGM), and/or descriptions of the available non-geospatial information (e.g., documents, algorithms and tools) using the Government Information Locator Service (GILS) metadata standard location. These metadata records are indexed using Wide Area Information Servers (WAIS) software, and are made available to Internet WAIS search clients communicating with the WAIS standard protocol (an early version of ANSI Z39.50).

### World-Wide Web

One of the most recent and user-friendly developments in the area of data access for the database community in general has been the use of the World Wide Web (WWW). For the METOC users in particular, access is via the Joint METOC Viewer (JMV). [7] Using JMV, METOC numerical data and products are available for downloading by geographic region. These data include surface pressures and temperatures. Still a wider variety of data are available for display as images in windows on the screen. For example, the user can display profiles and cross sections of three-dimensional atmospheric and oceanographic data [7]. The WWW has the advantage of being independent of the hardware platform because network browsers, using a common Hypertext Mark-up Language (HTML) protocol for net access, are available for many platforms [7].

## Object-Oriented Methods

Since 1985 [5, 6, 11], the object-oriented (OO) database design has been researched and developed for handling data that can not be managed easily using RDBMS. However, an object-oriented database is recommended to be implemented with applications of the same design. Otherwise, the advantage of the OO technology will be nullified in the heavy translation layer. To integrate an OO database with legacy applications, the full benefit of the technology may not be realized because of the need of a translation layer. The METOC RDBMS data server has experimented in using Common Object Request Broker Architecture (CORBA) to wrap a data object extracted from a METOC database and allow designated applications to access the data object in a "plug-and-play" mode. The wrapper is embedded and implemented in the APIs. The results demonstrated that though the CORBA-wrapper technology worked, the a re-evaluation of the system is still needed. However, the recent development of Java, an OO and platform-independent programming language developed by Sun Microsystem, should not be ignored. Because of its platform independence, Java can be used to control the protocol in downloading data objects from the data servers in a variety of different environments. A distributed database server can be constructed to take advantage of Java technology by using the WWW technology.

## Multimedia Technology

Though METOC data types have included images since late 1950s, they have existed largely in the single image or observation format. The emphasis of the METOC satellite technology has been on the quality and resolution of the data. Since the recent explosion of the "compute power" from a PC/NT workstation, PC/NT has been recognized as a bona fide data-processing and display workstation in the Department of Defense (DoD) systems. The directive of the Information Technology for the Twenty-First Century (IT21) is a reflection and an acknowledgment of this trend. The maturity of the multimedia hardware and software already has transformed the training and documentation technology. METOC data-monitoring and alerting functionality soon will adapt the technology as well. In the near future, the demand of the storage and retrieval of acoustic recordings along with other nature environmental data soon will push METOC data-server managers and engineers to consider the multimedia technology.

## Network Communication

The advances of the communication technology could overhaul the METOC data flow and the concept of operations. The change is likely to come from the virtual network capability first. All computers in DoD systems soon will be linked or addressable through some network. Further in the future, the communication bandwidth will overhaul the data-flow concept of operations. The bandwidth could change the data flow from the cascading "hub and spoke" concept to a point-to-point data flow concept. It can be envisioned easily that all applications (or clients) could come directly to the data-producing centers to obtain the desired data. When the data- producing centers implement fault-tolerant capabilities, a true federated database can be formulated through the wide bandwidth network. (See, for example [2]). However, this change will not come quickly since it is suspected that as the bandwidth increases, the data volume grows accordingly. The available portion of the shared bandwidth is likely to remain the same.

## V. DISCUSSION

In the next three years, the advances in scientific tools as well as new computer technologies inevitably will force changes in database design. Furthermore, the same advances also will change the user requirements. And, in turn the users will force the change in database server design. The METOC database server is poised to take advantages of these changes and technologies.

The METOC database-server design can take advantage of the extension of the communication network capability. The exist RDBMS capability already can be configured to formulate a distributed database-server capability. With the designated hierarchy of the data flow, applications can extracted data form a transparent distributed database server.

The metadata advances could possibly give the community the opportunity to link up the entire legacy database systems. This concept can be extended to imagine that all federal government (at least in the METOC community) database servers will have the capability to exchange data sets.

The WWW and Java constitute a significant advance in heterogeneous computer environments to provide a set of platform-independent protocols for data object transfer and processing. The METOC database-server engineers are examining such capability. As the effective communication bandwidth increases in the coming years, the "data pull" concept from individual applications can be fully implemented.

Though the METOC database server schema can be extended to accommodate the multimedia data type, the task is not straightforward. The METOC community has not explored fully the use of multimedia. The design of a data type in next two years to describe fully the attributes and services of multimedia will not be easy.

## VI. CONCLUSION

One of the most important conclusions is that not all technology can be mapped efficiently into METOC (or any) database. One needs to understand the requirements of the users and select the technology combinations that meet their needs as a priority. Typically, DoD systems cannot afford to upgrade constantly to new technology as soon as it becomes available. Moreover, if and when to use a technology and when not to use it is not always obvious. Therefore, a system designer must develop a list of criteria to consider when deciding if and where it is appropriate to use a technology. These criteria will be based on the trade offs, but always will include a view toward meeting users' requirements. When upgrading modern systems, engineers usually cannot obtain the full set of requirements at the onset of the project. The rapid technology advances combined with the new and modified user requirements often will invalidate the trade-off analysis at the beginning of the project. Therefore, modern systems must be constructed to anticipate and accommodate these advances and changes. METOC database uses the layered approach, unified design, data-centric perspective, and modular construction principles to accommodate the technology advances and requirement changes.

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## APPENDIX A - GLOSSARY

| | |
|---|---|
| ANSI | American National Standards Institute |
| ATS | Alert Threshold System |
| BT | Bathythermograph, Bathythermogram, or Bathythermography, depending on usage |
| BUFR | Binary Universal Form for the Representation of Meteorological data |
| $C^3I$ | Command, Control, Communications and Intelligence |
| CDBS | Central Database System or Central Database Server |
| COP | Common Operating Picture |
| CORBA | Common Object Request Broker Architecture |
| CSDGM | Content Standards for Digital Geospatial Metadata |
| DBMS | Database Management System |
| DII/COE | Defense Information Infrastructure Common Operating Environment |
| FGDC | Federal Geographic Data Committee |
| FNMOC | Fleet Numerical Meteorological and Oceanographic Center |
| FTP | File-Transfer Protocol |
| GILS | Government Information Locator Service |
| GRIB | Gridded Binary |

| | |
|---|---|
| GRID | Not an acronym but a data format |
| GUI | Graphical User Interface |
| HTML | Hypertext Markup Language |
| IME | Information Management Engineering |
| ITS | Image Translation Server |
| JMV | Joint METOC Viewer, a multiplatform client-server application suite that builds upon NODDS and WWW |
| JOTS 1 | Joint Operational Tactical System 1 |
| JMV | Joint METOC Viewer |
| METOC | Meteorological and Oceanographic |
| MIF | METOC Image Format |
| MRS | MINI Rawinsonde System |
| MUNIT | Modified Index of Refraction (M-Unit). An atmospheric Index of Refraction mathematically modified so that it substantially corrects for the curvature of the earth. (See NUNIT.) |
| NAVMACS | Naval Modular Automated Communications System |
| NEONS | Naval Environmental Operational Nowcasting System |
| NIPRNET | Navy Internet Protocol Routing Network |
| NITES | Navy Integrated Tactical Environmental Subsystem |
| NITF | National Image Transmission Format |
| NODDS | Navy Oceanographic Data Distribution System |
| NUNIT | Index of Refraction of the atmosphere (N-Unit). A measure of the amount of atmospheric refraction. It is the ratio of the wavelength of an electromagnetic wave in a vacuum to that in the atmosphere. NUNIT is not corrected for the curvature of the earth. (See MUNIT.) |
| OODBMS | Object-Oriented Database Management System |
| OSTR | Optimal Ship-Track Route |
| OTCIXS | Officer in Tactical Command Information Exchange Subsystem |
| OTH-T-Gold | Over-the-Horizon-Targeting Gold (a message format) |
| OVLY2 | Overlay 2 (Part of OTH-T specifications) |
| RDBMS | Relational Database Management System |
| RDSND | Radiosond message format for OTH-T messages |
| SIPRNET | Secret Internet Protocol Routing Network |
| SMOOS | Shipboard Meteorological and Oceanographic Observing System |
| AN/SMQ-11 | Army/Navy satellite receiver for the military satellite counterpart of the GOES |
| SQL-92 | Structured-Query Language specified by ANSI X3.135-1992 |
| TAF | Terminal Aerodrome Forecast |
| TDBM | Track Database Manager |
| TEDS | Tactical Environmental Data System |
| TESS/NC | Tactical Environmental Support System/Next Century |
| WAIS | Wide Area Information Servers |
| WMO | World Meteorological Organization |
| W W W | World Wide Web |

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This paper presents a brief description of the Meteorological and Oceanographic (METOC) system and a discussion of various aspects of the METOC database that emphasizes the importance of combining new and existing technology. The METOC database components were designed according to a database-centric architecture to assist the users in obtaining up-to-date information from the DII/COE compliant METOC system. The Meteorological and Oceanographic (METOC) database is a dynamic, distributed database that conforms to the DII/COE requirement of providing general availability to all users of the system. Several key aspects of METOC database technology are of interest to various users who have special requirements. Because each key aspect must be implemented in concert with users requirements, some adaptations may be necessary. The most important feature of a database server from the user perspective is its capability to deliver to the user the required information in a timely and user-friendly manner. This paper discusses various aspects of the impact of technology evolution on the METOC database and its impact on the system design and development cycle.

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